5.0 Potential Radiation Doses from 1995 Hanford Operations

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During 1995, radionuclides reached the environment in gaseous and liquid effluents from Hanford operations. Gaseous effluents were released from operating stacks and ventilation exhausts. Liquid effluents were released from operating waste-water treatment facilities and from contaminated ground water seeping into the Columbia River.

Potential radiological doses to the public from these releases were evaluated in detail to determine compliance with pertinent regulations and limits. The radiological impacts of 1995 Hanford operations were assessed in terms of the following:

- dose to a hypothetical maximally exposed individual at an offsite location
- maximum dose rate from external radiation at a publicly accessible location on or within the Site boundary
- dose to an avid sportsman who consumes wildlife exposed to radionuclides onsite
- dose to the population residing within 80 km (50 mi) of the Hanford operating areas
- absorbed dose rate (rad/d) received by animals caused by radionuclide releases to the Columbia River.

It is generally accepted that radiological dose assessments should be based on direct measurements of radiation dose rates and radionuclide concentrations in the surrounding environment. The amounts of most radioactive materials released during 1995 were generally too small to be measured directly once they were dispersed in the offsite environment. For many of the measurable radionuclides, it was difficult to identify the contributions from Hanford sources in the presence of contributions from worldwide fallout and from naturally occurring uranium and its decay products. Therefore, in nearly all instances, offsite doses were estimated using environmental pathway models that calculate concentrations of radioactive materials in the environment from effluent releases reported by the operating contractors.

As in the past, radiological doses from the water pathway were calculated based on the differences in radionuclide concentrations between upstream and downstream sampling points. During 1995, tritium, strontium-90, technetium-99, and isotopes of uranium were found in the Columbia River downstream of Hanford at greater concentrations than predicted based on direct discharge from the 100 Areas. Riverbank spring water containing these radionuclides is known to enter the river along the portion of shoreline extending from the old Hanford Townsite to downstream of the 300 Area (see Section 4.2, “Surface Water and Sediment Surveillance”). No direct discharges from the 300 Area to the Columbia River were reported in 1995.

The radiological doses[(a)] to the public from Hanford operations in 1995 were calculated for a hypothetical maximally exposed individual and for the collective population residing within 80 km (50 mi) of the Hanford Site. These doses were calculated from effluent releases reported by the operating contractors, and radionuclide measurements in environmental media, using the GENII computer code Version 1.485 (Napier et al. 1988a, 1988b, 1988c) and Hanford Site-specific parameters listed in Appendix D and in Bisping (1996).

The dose to the maximally exposed individual from Hanford operations in 1995 was potentially 0.02 mrem (2×10^{-4} mSv), compared to 0.04 mrem (4×10^{-4} mSv) reported for 1994. The dose to the local population of

(a) Unless stated otherwise, the term “dose” in this section is the “total effective dose equivalent” (see Appendix B, “Glossary”).

380,000 (Beck et al. 1991) from 1995 operations was 0.3 person-rem (0.003 person-Sv), compared to 0.6 person-rem (0.006 person-Sv) reported for 1994. The 1995 average dose to the population was about 0.0009 mrem (9×10^{-6} mSv) per person. The current DOE radiation dose limit for an individual member of the public is 100 mrem/yr (1 mSv/yr) from all pathways and 10 mrem/y (0.1 mSv/y) from airborne radionuclide emissions. The national average dose from natural sources is 300 mrem/yr (3 mSv/yr). Thus, 1995 Hanford emissions potentially contributed to the maximally exposed individual a dose equivalent to only 0.02% of the DOE dose limit, or 0.01% of the average dose received from natural radioactivity in the environment. For the average member of the local population, these contributions were 0.001% and 0.0003%, respectively.

The uncertainty associated with the radiological dose calculations on which this report is based has not been quantified. However, when Hanford-specific data were not available for parameter values (for example, vegetation uptake and consumption factors), conservative values were selected from the literature for use in environmental transport models. Thus, radiation doses calculated using environmental models should be viewed as hypothetical maximum estimates of doses resulting from Hanford operations.

Maximally Exposed Individual Dose

The maximally exposed individual is a hypothetical person who lives at a location and has a postulated lifestyle such that it is unlikely that other members of the public would receive higher radiation doses. This individual's diet, dwelling place, and other factors were chosen to maximize the combined doses from all reasonable environmental pathways of exposure to radionuclides in Hanford effluents. In reality, such a combination of maximized parameters is unlikely to apply to any one individual.

The location of the maximally exposed individual can vary from year to year depending on the relative importance of the several sources of radioactive effluents released to the air and to the Columbia River from Hanford facilities. Historically, two separate locations in the Hanford environs have been used to assess the dose to the maximally exposed individual: the Ringold area, 26 km (16 mi) east of the 200 Areas separation facilities, and the Riverview irrigation district across the river from Richland (Figure 5.0.1). The Ringold location is closer than Riverview to Hanford facilities that were the major contributors of airborne effluents in the past. At Riverview, the maximally exposed individual has the highest exposure to radionuclides in the Columbia River. Since 1993, a third location has been considered because of the shift in Site operations from strategic materials production to the current mission of research and environmental restoration. This change has resulted in decreased significance in the air emissions from the 200-Area production facilities relative to the activity in the 300 Area, i.e., the shift in the location of the maximally exposed individual is mainly due to the reduction in releases at the 100 and 200 Areas and increased activity in the 300 Area. Therefore, a receptor directly across the river from the 300 Area, at Sagemoor, would be maximally exposed to airborne radionuclides from those facilities. The applicable exposure pathways for each of these locations are described in the following.

The Ringold location is situated to maximize the air pathway exposures from emissions at the 200 Area facilities, including direct exposure to the plume, inhalation, external exposure to radionuclides that deposit on the ground, and ingestion of locally grown food products. In addition, it is assumed that individuals at the Ringold location irrigate their crops with water taken from the Columbia River downstream of where ground water enters the river from the 100 Areas and 200-East Area (Figure 4.8.17). This results in additional exposures from ingestion of irrigated food products and external irradiation from radionuclides deposited on the ground by irrigation. Recreational use of the Columbia River is also considered for this individual, resulting in direct exposure from water and radionuclides deposited on the shoreline and internal dose from ingestion of locally caught fish.

The Riverview receptor is assumed to be exposed via the same pathways as the individual at Ringold, except that irrigation water from the Columbia River may contain radionuclides that enter the river at the 300 Area, in addition to those from upstream release points. This individual is also assumed to obtain domestic water from the river via a local water treatment system. Exposure to this individual from the air pathways is typically lower than exposure at Ringold because of the greater distance from the major onsite emission sources.

The individual at Sagemoor (assumed to be located 1.5 km [1 mi] directly across the Columbia River from

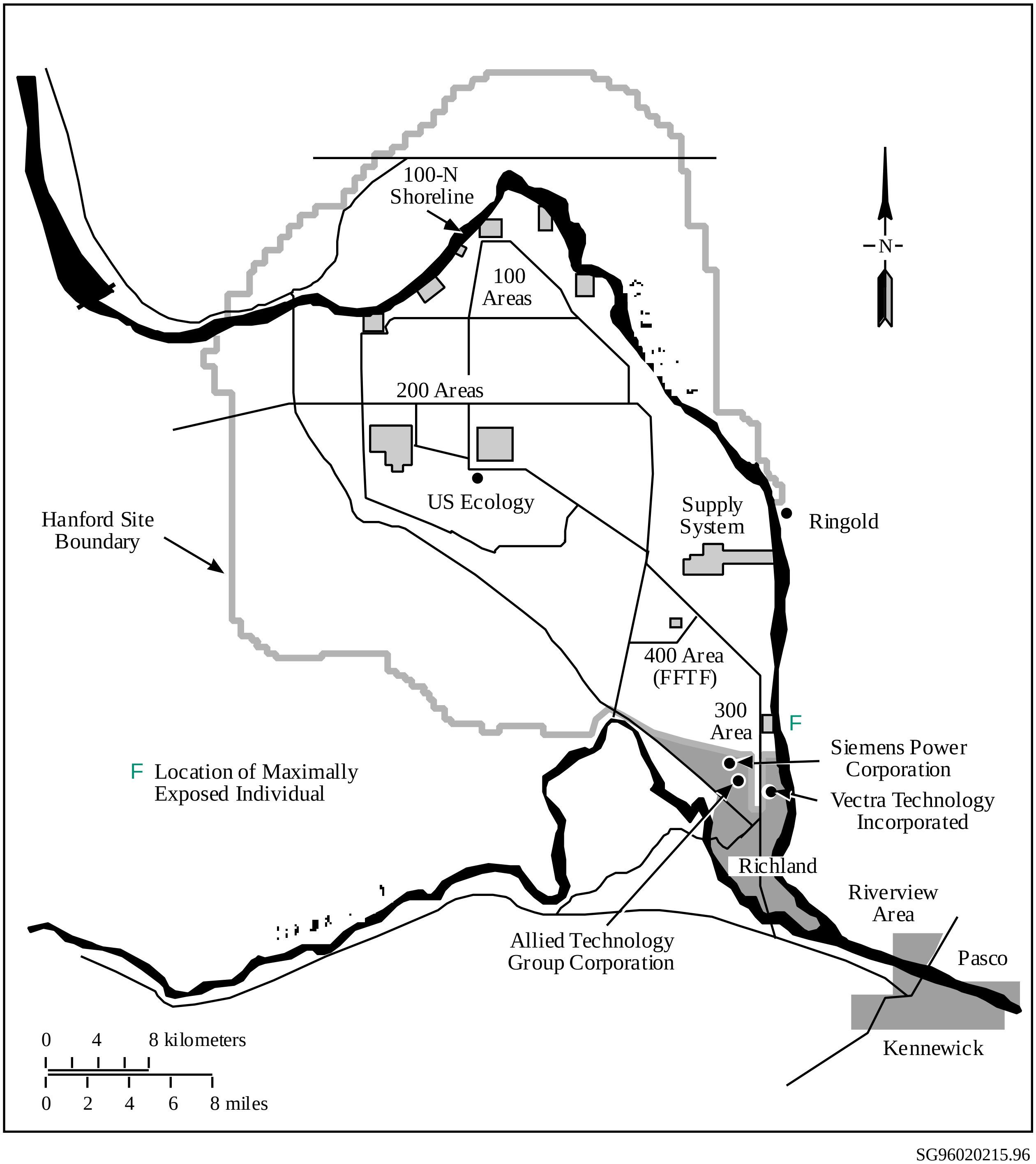

Figure 5.0.1. Locations Important to Dose Calculations

the 300 Area) receives maximum exposure to airborne effluents from the 300 Area, including the same pathways as the individual at Ringold. Domestic water at this location comes from a well rather than from the river, and wells in this region are not contaminated by radionuclides of Hanford origin (DOH 1988). Although the farms located across from the 300 Area obtain irrigation water from upstream of the Hanford Site, the conservative assumption was made that the diet of the maximally exposed individual residing across from the 300 Area consisted totally of foods purchased from the Riverview area, which could contain radionuclides present in both liquid and gaseous effluents from Hanford. The added contribution of radionuclides in the Riverview irrigation water maximizes the calculated dose from all air and water pathways combined.

During 1995, the hypothetical maximally exposed individual at Sagemoor was calculated to have received a slightly higher dose than a maximally exposed individual located at either Ringold or Riverview. Radiation doses to the maximally exposed individual were calculated using the effluent data in Section 3.1, Tables 3.1.1, and 3.1.4. Quantities of radionuclides assumed to be present in the Columbia River from riverbank springs were also calculated for input to the GENII code. The estimated releases to the river from these sources were derived from the difference between the upstream and downstream concentrations. These radionuclides were assumed to enter the river through ground-water seeps between the old Hanford Townsite and the 300 Area. The calculated doses for the maximally exposed individual are summarized in Table 5.0.1. These values include the doses received from exposure to liquid and airborne effluents during 1995, as well as the future, or committed dose from radionuclides that were inhaled or ingested during 1995. As releases from facilities and the doses from these sources decrease, the contribution of diffuse sources, such as wind-blown contaminated soil, becomes relatively more significant. An upper estimate of the dose from diffuse sources is discussed in a following subsection ("Comparison with Clean Air Act Standards"). The estimated dose from diffuse sources was similar to the dose reported in Table 5.0.1 for measured emissions. Site-specific parameters for food pathways, diet, and recreational activity used for the dose calculations are contained in Appendix D.

The total radiation dose to the hypothetical maximally exposed individual in 1995 was calculated to be 0.02 mrem (2×10^{-4} mSv) compared to 0.04 mrem (4×10^{-4} mSv) calculated for 1994. The primary pathways contributing to this dose (and the percentage of all pathways) were:

- consumption of food irrigated with Columbia River water containing radionuclides (38%), principally tritium and uranium

Table 5.0.1. Dose to the Hypothetically Maximally Exposed Individual Residing 1.5 km East of the 300 Area in 1995

		Operating Area Contribution Doses, mrem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	1.0×10^{-4}	2.0×10^{-6}	5.2×10^{-5}	2.2×10^{-8}	1.5×10^{-4}
	Inhalation	4.0×10^{-5}	2.1×10^{-4}	5.2×10^{-3}	1.4×10^{-5}	5.5×10^{-3}
	Foods	1.1×10^{-6}	8.3×10^{-4}	5.9×10^{-5}	2.4×10^{-7}	8.9×10^{-4}
	Subtotal air	1.4×10^{-4}	1.0×10^{-3}	5.3×10^{-3}	1.4×10^{-5}	6.5×10^{-3}
Water	Recreation	3.5×10^{-6}	7.0×10^{-5}	0.0	0.0	7.3×10^{-5}
	Foods	6.4×10^{-4}	8.2×10^{-3}	0.0	0.0	8.8×10^{-3}
	Fish	6.1×10^{-4}	6.5×10^{-3}	0.0	0.0	7.1×10^{-3}
	Subtotal water	1.3×10^{-3}	1.5×10^{-2}	0.0	0.0	1.6×10^{-2}
Combined total		1.4×10^{-3}	1.6×10^{-2}	5.3×10^{-3}	1.4×10^{-5}	2.3×10^{-2}

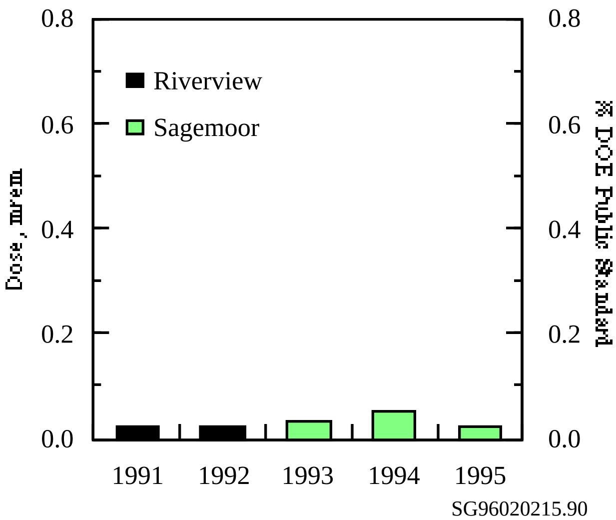

Figure 5.0.2. Calculated Effective Dose Equivalent to the Hypothetical Maximally Exposed Individual, 1991 Through 1995

- consumption of Columbia River fish containing radionuclides (31%), principally isotopes of uranium
- inhalation of airborne radionuclides (24%), principally lead-212 released from the 300 Area.

The DOE radiological dose limit for any member of the public from all routine DOE operations is 100 mrem/yr (1 mSv/yr). The dose calculated for the maximally exposed individual for 1995 was 0.02% of the DOE limit.

The doses from Hanford operations for the maximally exposed individual for 1991 through 1995 are illustrated in Figure 5.0.2. During each year, the doses were estimated using methods and computer codes that were state-of-the-art at the time. From 1991 to 1992, the maximally exposed individual was located at either Ringold or Riverview, whichever location represented the maximum hypothetical dose. For 1993 through 1995, the hypothetical maximally exposed individual was located across the Columbia River from the 300 Area.

Special Case Exposure Scenarios

Exposure parameters used to calculate the dose to the maximally exposed individual are selected to define a high-exposure scenario that is unlikely to occur. Such a scenario does not necessarily result in the highest conceivable radiological dose. Low-probability exposure scenarios exist that could result in somewhat higher doses. Two scenarios that could lead to larger doses include an individual who could spend time at the Site boundary location with the maximum external radiation dose rate and a sportsman who might consume contaminated wildlife that migrated from the Site. These special cases are discussed below, as is the dose from consumption of drinking water at the Fast Flux Test Facility.

Maximum "Boundary" Dose Rate

The "boundary" radiation dose rate is the external radiation dose rate measured at publicly accessible locations on or near the Site. The "boundary" dose rate was determined from radiation exposure measurements using thermoluminescent dosimeters at locations of expected elevated dose rates onsite and at representative locations offsite. These boundary dose rates should not be used to calculate annual doses to the general public because no one can actually reside at any of these boundary locations. However, these rates can be used to determine the dose to a specific individual who might spend some time at that location.

External radiation dose rates measured in the vicinity of the 100-N, 200, 300, and 400 (Fast Flux Test Facility) Areas are described in Section 4.7, "External Radiation Surveillance." The 200 Areas results were not used because these locations are not accessible to the public. Radiation measurements made at the 100-N Area shoreline (Figure 5.0.1) were consistently above the background level and represent the highest measured boundary dose rates. The Columbia River provides public access to an area within a few hundred meters of the N Reactor and supporting facilities.

The annual average dose rate at the location with the highest exposure rate along the 100-N shoreline during 1995 was 0.02 mrem/h (2×10^{-4} mSv/h), or about twice the average background dose rate of 0.01 mrem/h (1×10^{-4} mSv/h) normally observed at offsite shoreline locations. Therefore, for every hour someone spent at the 100-N Area shoreline during 1995, the external radiation dose received from Hanford operations would be about 0.01 mrem (1×10^{-4} mSv) above the natural background dose. If an individual spent 2 hours at this location they would receive a dose similar to the annual dose calculated for the hypothetical maximally exposed individual at Sagemoor. The public can approach the shoreline by boat, but they are legally restricted from stepping onto the shoreline. Therefore, an individual is unlikely to remain on or near the shoreline for an extended period of time.

Sportsman Dose

Wildlife have access to areas of the Site that contain radioactive materials, and some do become contaminated. Sometimes contaminated wildlife travel offsite. Sampling is conducted onsite to estimate maximum contamination levels that might possibly exist in animals hunted offsite. Since this scenario has a relatively low probability of occurring, these doses are not included in the maximally exposed individual calculation.

Listed below are estimates of the radiation doses that could have resulted if wildlife containing the maximum concentrations measured in onsite wildlife in 1995 migrated offsite, were hunted, and were eaten.

- The dose from eating 1 kg (2.2 lb) of deer meat containing the maximum concentration of cesium-137 (0.037 pCi/g) measured in a deer collected onsite is estimated to be 2 x 10^{-3} mrem (2 x 10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of whitefish or sucker meat containing the maximum concentrations of cesium-137 (0.04 pCi/g) measured in whitefish or suckers collected from the Hanford Reach of the Columbia River is estimated to be 2 x 10^{-3} mrem (2 x 10^{-5} mSv).

- The dose from eating 1 kg (2.2 lb) of goose meat containing the maximum concentration of cesium-137 (0.007 pCi/g) measured in a Canada goose collected onsite is estimated to be 4 x 10^{-4} mrem (4 x 10^{-6} mSv).

These are very low doses, and qualitative observations suggest that the significance of this pathway is further reduced because of the relatively low migration offsite (Eberhardt et al. 1982) and the inaccessibility of onsite wildlife to hunters. The methodology for calculating doses from consumption of wildlife, was to multiply the maximum concentration measured in edible tissue by a dose conversion factor for ingestion of that tissue and, are addressed in more detail in Soldat et al. (1990).

Fast Flux Test Facility Drinking Water

The Fast Flux Test Facility Visitors Center, located southeast of the Fast Flux Test Facility Reactor building (Figure 5.0.1), was not open to the public during 1995. Ground water was therefore not used as a public drinking water source, and no calculation of potential dose to the public was performed for this facility.

During 1995, ground water was used as drinking water by workers at the Fast Flux Test Facility. Therefore, this water was sampled and analyzed throughout the year in accordance with applicable drinking water regulations. All annual average radionuclide concentrations measured during 1995 were well below applicable drinking water standards, but concentrations of tritium were detected at levels greater than typical background values (see Section 4.3, "Hanford Site Drinking Water Surveillance"). Based on the measured concentrations, the potential dose to Fast Flux Test Facility workers (an estimate derived by assuming a consumption of 1 L/d for 240 working days), the worker would receive a dose of 0.2 mrem (0.002 mSv). Of this total, drinking water obtained from the emergency back-up ground-water well 499-S0-7 during June and July 1995 accounted for 0.05 mrem (see Appendix D, Table D.10).

Comparison with Clean Air Act Standards

Limits for radiation dose to the public for airborne emissions from DOE facilities are provided in 40 CFR 61, Subpart H, of the Clean Air Act Amendments. The regulation specifies that no member of the public shall receive a dose of more than 10 mrem/yr (0.1 mSv/yr) (EPA 1989) from exposure to airborne radionuclide effluents (other than radon) released at DOE facilities. It also requires that each DOE facility submit an annual report that supplies information about atmospheric emissions for the preceding year and their potential offsite impacts. The following summarizes information that is provided in more detail in the 1995 air emissions report (Gleckler et al. 1996).

The 1995 air emissions from monitored Hanford facilities, including radon-220 and radon-222 releases from the 327 building in the 300 Area, resulted in a potential dose to a maximally exposed individual across from the 300 Area of 0.006 mrem (6 x 10^{-5} mSv), which is 0.06% of the limit. Of this total, radon emissions from the 327 building contributed 0.0035 mrem, and non-radon emissions from all stack sources contributed 0.0029 mrem. Therefore, the estimated annual dose from monitored stack releases at the Hanford Site during 1995 was well below the Clean Air Act standard. The Clean Air Act requires the use of CAP88-PC or other EPA models to demonstrate compliance with the standard, and the assumptions embodied in these codes differ slightly from standard assumptions used at the Hanford Site for reporting to DOE via this document. Nevertheless, the result of calculations performed with CAP88-PC for air emissions from Hanford facilities agrees well with that calculated using the GENII code (0.006 mrem or 6 x 10^{-5} mSv).

The December 1989 revisions to the Clean Air Act (40 CFR 61, Subpart H) also require DOE facilities to estimate the dose to a member of the public for radionuclides released from all potential sources of airborne radionuclides. DOE and EPA have interpreted the regulation to include diffuse and unmonitored sources as well as monitored point sources. The EPA has not specified or approved methods for estimating emissions from diffuse sources, and standardization is difficult because of the wide variety of such sources at DOE sites. Estimates of potential diffuse source emissions at the Hanford Site have been developed using environmental surveillance measurements of airborne radionuclides at the Site perimeter.

During 1995, the estimated dose from diffuse sources to the maximally exposed individual across the river from the 300 Area was 0.02 mrem (2 x 10^{-4} mSv), which was greater than the estimated dose at that location from stack emissions (0.006 mrem or 6 x 10^{-5} mSv). Doses at other locations around the Hanford Site perimeter ranged from 0.02 to 0.03 mrem (2 x 10^{-4} to 3 x 10^{-4} mSv). Based on these results, the combined dose from stack emissions and diffuse and unmonitored sources during 1995 was much less than the EPA standard.

Collective Dose to the Population Within 80 km (50 mi)

Exposure pathways for the general public from releases of radionuclides to the atmosphere include inhalation, air submersion, and consumption of contaminated food. Pathways of exposure for radionuclides present in the Columbia River include consumption of drinking water, fish, and irrigated foods, and external exposure during aquatic recreation. The regional collective dose from 1995 Hanford operations was estimated by calculating the radiation dose to the population residing within an 80-km (50-mi) radius of the onsite operating areas. Results of the dose calculations are shown in Table 5.0.2. Food pathway, dietary, residency, and recreational activity assumptions for these calculations are given in Appendix D.

Table 5.0.2. Dose to the Population from 1995 Hanford Operations

		Operating Area Contribution Doses, person-rem				
Effluent	Pathway	100 Areas	200 Areas	300 Area	400 Area	Pathway Total
Air	External	7.8 x 10^{-6}	1.3 x 10^{-4}	5.8 x 10^{-4}	7.1 x 10^{-7}	7.2 x 10^{-4}
	Inhalation	2.4 x 10^{-3}	2.1 x 10^{-2}	3.8 x 10^{-2}	6.7 x 10^{-4}	6.2 x 10^{-2}
	Foods	8.3 x 10^{-5}	9.9 x 10^{-2}	2.6 x 10^{-3}	2.3 x 10^{-5}	1.0 x 10^{-1}
	Subtotal air	2.5 x 10^{-3}	1.2 x 10^{-1}	4.1 x 10^{-2}	6.9 x 10^{-4}	1.6 x 10^{-1}
Water	Recreation	1.9 x 10^{-5}	4.0 x 10^{-4}	0.0	0.0	4.2 x 10^{-4}
	Foods	6.7 x 10^{-4}	8.6 x 10^{-3}	0.0	0.0	9.3 x 10^{-3}
	Fish	2.3 x 10^{-4}	2.4 x 10^{-3}	0.0	0.0	2.6 x 10^{-3}
	Drinking water	1.7 x 10^{-3}	1.5 x 10^{-1}	0.0	0.0	1.5 x 10^{-1}
	Subtotal water	2.6 x 10^{-3}	1.6 x 10^{-1}	0.0	0.0	1.6 x 10^{-1}
Combined total		5.1 x 10^{-3}	2.8 x 10^{-1}	4.1 x 10^{-2}	6.9 x 10^{-4}	3.3 x 10^{-1}

The collective dose calculated for the population was 0.3 person-rem (0.003 person-Sv) in 1995, compared to 0.6 person-rem (0.006 person-Sv) in 1994. The 80-km (50-mi) collective doses attributed to Hanford operations from 1991 through 1995 are compared in Figure 5.0.3.

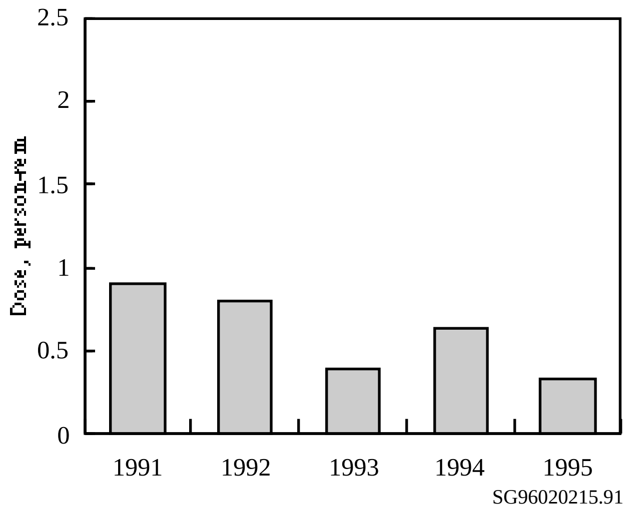

Figure 5.0.3. Calculated Effective Dose Equivalent to the Population Within 80 km (50 mi) of the Hanford Site, 1991 Through 1995

Primary pathways contributing to the 1995 dose to the population were

- consumption of drinking water (46%) contaminated with radionuclides released to the Columbia River at Hanford, principally tritium and uranium
- consumption of foodstuffs (30%) contaminated with radionuclides released in gaseous effluents, primarily iodine-129 from the Plutonium-Uranium Extraction Plant stack
- inhalation of radionuclides (19%) that were released to the air, principally iodine-129 from the Plutonium-Uranium Extraction Plant stack.

The average per capita dose from 1995 Hanford operations, based on a population of 380,000 within 80 km (50 mi), was 0.0009 mrem (9×10^{-6} mSv). To place this dose from Hanford activities into perspective, the estimate may be compared with doses from other routinely encountered sources of radiation such as natural terrestrial and cosmic background radiation, medical treatment and X rays, natural radionuclides in the body, and inhalation of naturally occurring radon. The national average radiation doses from these other sources are illustrated in Figure 5.0.4. The estimated average per capita dose to members of the public from Hanford sources is only approximately 0.0003% of the annual per capita dose (300 mrem) from natural background sources.

The doses from Hanford effluents to the maximally exposed individual and to the population within 80 km (50 mi) are compared to appropriate standards and natural background radiation in Table 5.0.3. This table shows that the calculated radiological doses from Hanford operations in 1995 are a small percentage of the standards and of natural background.

Doses from Other Than DOE Sources

Various non-DOE industrial sources of public radiation exposure exist at or near the Hanford Site. These include the low-activity commercial radioactive waste burial ground at Hanford operated by US Ecology, the nuclear generating station at Hanford operated by Washington Public Power Supply System, the nuclear fuel production plant operated by Siemens Power Corporation, the commercial low-activity radioactive waste compacting facility operated by Allied Technology Group Corporation, and a commercial decontamination facility operated by Vectra Technology, Inc. (Figure 5.0.1). DOE maintains an awareness of other manmade sources of radiation which, if combined with the DOE sources, might have the potential to cause a dose exceeding 10 mrem (0.1 mSv) to any member of the public. With information gathered from these companies, it was conservatively estimated that the total 1995 individual dose from their combined activities is on the order of 0.05 mrem (5×10^{-4} mSv). Therefore, the combined dose from Hanford area non-DOE and DOE sources to a member of the public for 1995 was well below any regulatory dose limit.

Hanford Public Radiation Dose in Perspective

This section provides information to put the potential health risks of radionuclide emissions from the Hanford

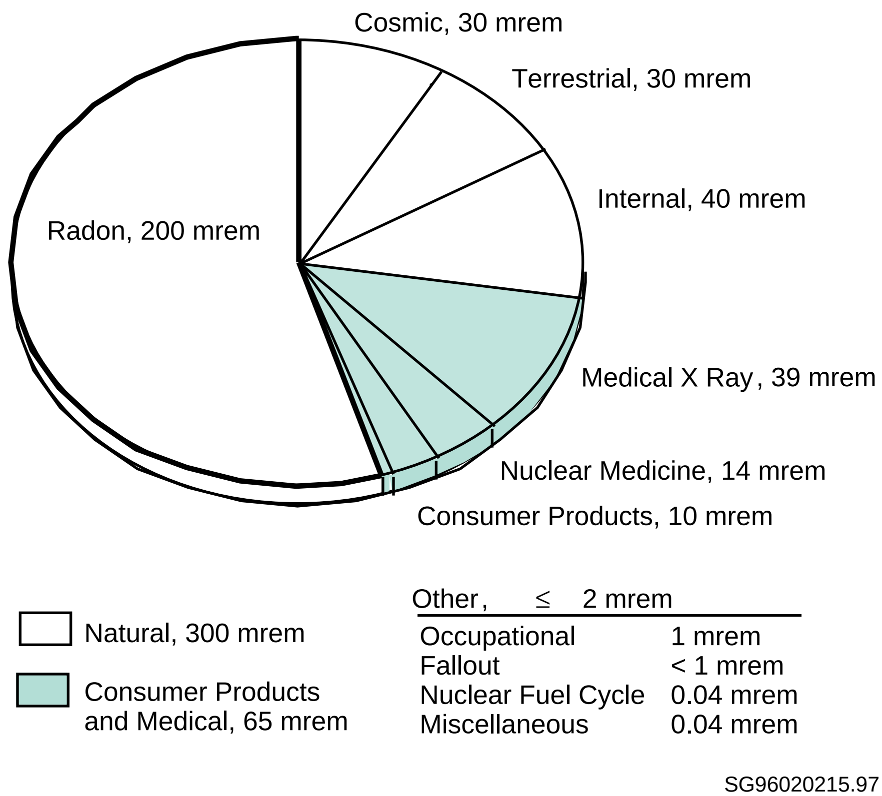

Figure 5.0.4. National Annual Average Radiation Doses from Various Sources (mrem) (NCRP 1987)

Table 5.0.3. Summary of Doses to the Public in the Vicinity of Hanford from Various Sources, 1995

Source	Maximum Individual, mrem[(a)]	80-km Population, person-rem[(a)]
All Hanford effluents[(b)]	0.02	0.3
DOE limit	100	--
Percent of DOE limit	0.02%	--
Background radiation	300	110,000
Hanford doses percent of background	<0.01%	3×10^{-4} %
Doses from gaseous effluents[(c)]	0.006	--
EPA air standard	10	--
Percent of EPA standard	0.06%	--

(a) To convert the dose values to mSv or person-Sv, divide them by 100.
(b) Calculated with the GENII code (Napier et al. 1988a, 1988b, 1988c).
(c) Calculated with the EPA CAP88-PC code.

Site into perspective. Several scientific studies (NRC 1980, 1990; UNSCEAR 1988) have been performed to estimate the possible risk of detrimental health effects from exposure to low levels of radiation. These studies have provided vital information to government and scientific organizations that recommend radiation dose limits and standards for public and occupational safety.

Although no increase in the incidence of health effects from low doses of radiation has actually been confirmed by the scientific community, most scientists accept the hypothesis that low-level doses might increase the probability of certain types of effects, such as cancer. Regulatory agencies conservatively (cautiously) assume that the probability of these types of health effects at low doses (down to zero) is proportional to the probability per unit dose of these same health effects observed historically at much higher doses (in atomic bomb victims, radium dial painters, etc.). Under these assumptions, even natural background radiation (which is hundreds of times greater than radiation from current Hanford releases) increases each person's probability or chance of developing a detrimental health effect.

Not all scientists agree on how to translate the available data on health effects into the numerical probability (risk) of detrimental effects from low-level radiation doses. Some scientific studies have indicated that low radiation doses may cause beneficial effects (HPS 1987). Because cancer and hereditary diseases in the general population may be caused by many sources (e.g., genetic defects, sunlight, chemicals, and background radiation), some scientists doubt that the risk from low-level radiation exposure can ever be conclusively proved. In developing Clean Air Act regulations, EPA uses a probability value of approximately 4 per 10 million (4×10^{-7}) for the risk of developing a fatal cancer after receiving a dose of 1 mrem (0.01 mSv) (EPA 1989). Recent data (NRC 1990) support the reduction of even this small risk value, possibly to zero, for certain types of radiation when the dose is spread over an extended time.

Government agencies are trying to determine what level of risk is safe for members of the public exposed to pollutants from industrial activities (for example, DOE facilities, nuclear power plants, chemical plants, and hazardous waste sites). All of these industrial activities are considered beneficial to people in some way, such as providing electricity, national defense, waste disposal, and consumer products. These government agencies have a complex task in establishing environmental regulations that control levels of risk to the public without unnecessarily reducing needed benefits from industry.

One perspective on risks from industrial activities is to compare them to risks involved in other typical activities. For instance, two risks that an individual receives from flying on an airline are the risks of added radiation dose (from a stronger cosmic radiation field that exists at higher altitudes) and the possibility of being in an aircraft accident. Table 5.0.4 compares the estimated risks from various radiation doses to the risks of some activities encountered in everyday life.

The risk of detrimental health effects from Hanford radioactive releases are illustrated in Table 5.0.5. Listed are some activities considered approximately equal in risk to the risk from the dose received by the maximally exposed individual from monitored Hanford effluents in 1995 (excluding diffuse or unmonitored sources).

Dose Rates to Animals

Conservative (upper) estimates have been made of radiological dose to "native aquatic organisms," in accordance with a DOE Order 5400.5 interim requirement for management and control of liquid discharges. Possible radiological dose rates during 1995 were calculated for several exposure modes, including exposure to radionuclides in water entering the Columbia River from springs near the 100-N Area, and internally deposited radionuclides measured in samples of animals collected from the river and onsite. Because the water flow of the springs at the 100-N Area is so low, no aquatic animal can live directly in this spring water. Exposure to the radionuclides from the springs cannot occur until the spring water has been noticeably diluted in the Columbia River. The assumption was made that a few aquatic animals might be exposed to the maximum concentration of radionuclides measured in the spring water (see Table 3.2.5) after dilution of 10 to 1 by the river. Radiological doses were calculated for several different types of aquatic animals, using these highly conservative assumptions and the computer code CRITR2 (Baker and Soldat 1992). The animal receiving the highest potential dose was a duck consuming aquatic plants. However, even if a duck spent 100% of its time in the one-tenth diluted spring water and consumed only plants growing there, it would receive a radiation dose rate of 4×10^{-5} rad/d. This dose rate is 0.004% of the limit of

Table 5.0.4. Estimated Risk from Various Activities and Exposures[a]

Activity or Exposure Per Year	Risk of Fatality
Riding or driving in a passenger vehicle (300 miles)	2×10^{-6}[b]
Home accidents	100×10^{-6}[b]
Drinking 1 can of beer or 4 ounces of wine per day (liver cancer/cirrhosis)	10×10^{-6}
Pleasure boating (accidents)	6×10^{-6}[b]
Firearms, sporting (accidents)	10×10^{-6}[b]
Smoking 1 pack of cigarettes per day (lung/heart/other diseases)	$3{,}600 \times 10^{-6}$
Eating 4 tablespoons of peanut butter per day (liver cancer)	8×10^{-6}
Eating 90 pounds of charcoal-broiled steaks (gastrointestinal-tract cancer)	1×10^{-6}
Drinking chlorinated tap water (trace chloroform—cancer)	3×10^{-6}
Taking contraceptive pills (side effects)	20×10^{-6}
Flying as an airline passenger (cross country roundtrip—accidents)	8×10^{-6}[b]
Flying as an airline passenger (cross country roundtrip—radiation)	0 to 5×10^{-6}
Natural background radiation dose (300 mrem, 3 mSv)	0 to 120×10^{-6}
Dose of 1 mrem (0.01 mSv)	0 to 0.4×10^{-6}
Dose to the maximally exposed individual living near Hanford in 1995 (0.02 mrem, 2×10^{-4} mSv)	0 to 0.01×10^{-6}

(a) These values are generally accepted approximations with varying levels of uncertainty; there can be significant variation as a result of differences in individual lifestyle and biological factors (Ames et al. 1987; Atallah 1980; Dinman 1980; Travis and Hester 1990; Wilson and Crouch 1987).

(b) Real actuarial values. Other values are predicted from statistical models. For radiation dose, the values are reported in a possible range from the least conservative (0) to the currently accepted most conservative value.

Table 5.0.5. Activities Comparable in Risk to That from the 0.02-mrem Dose Calculated for the 1995 Maximally Exposed Individual

Driving or riding in a car 3 km (1.8 mi)
Smoking 3/100 of a cigarette
Flying 8 km (5 mi) on a commercial airline
Eating 2.4 tablespoons of peanut butter
Eating one 0.5-kg (1.1-lb) charcoal-broiled steak
Drinking about 2.9 L (3 quarts) of chlorinated tap water
Being exposed to natural background radiation for about 56 minutes in a typical terrestrial location
Drinking about one-half of a can of beer or one-half of a glass of wine

1 rad/d for native aquatic animal organisms established by DOE Order 5400.5 and is not expected to cause detrimental effects to animal populations.

Doses were also estimated for clams, fish, and waterfowl living in the Columbia River. The highest potential dose from all the radionuclides reaching the Columbia River from Hanford sources during 1995 was 5×10^{-3} rad/d for a duck that consumed contaminated vegetation. Dose estimates based on the maximum concentrations of cesium-137 measured in muscle of animals collected onsite and from the Columbia River ranged from 2×10^{-7} rad/d for a Canada goose to 1×10^{-6} rad/d for a mule deer.